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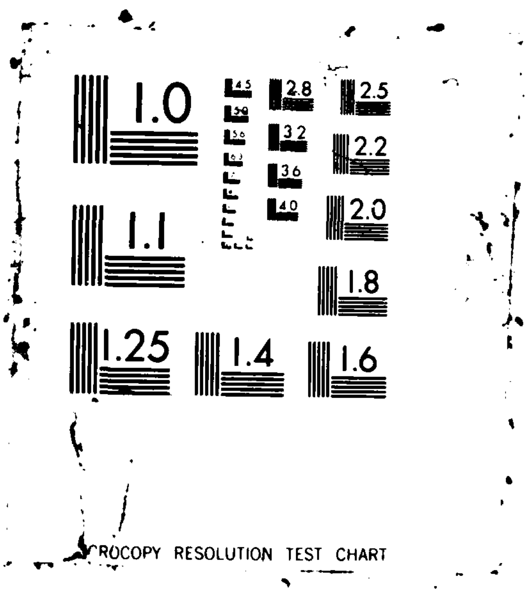
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TECHNICAL REPORT RD-RE-86-7

MESOSCALE WIND VARIABILITY IN THE VICINITY OF BERLIN, GERMANY

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JANUARY 1987

U.S. ARMY MISSILE COMMAND
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Mesoscale wind variability over a 35 mile (56 km) distance in the vicinity of Berlin, Germany is discussed in this report. Horizontal differences in windspeed (scalar shear) and wind direction (angular differences) are utilized to compute the deviation of the windspeed and direction (wind-shear) from one measurement location to another at the constant pressure levels: Surface, 1000 mb (near surface), 850 mb (1.5 km), 700 mb (3 km), and 500 mb (5.5 km). Results from other wind variability studies that have appeared in the literature have been obtained from special observing networks, which provided either a limited number of total observations, or many observations concentrated over a period of a few days. The close proximity of two upper-air stations provides an opportunity to establish a climatology of horizontal wind variation. Frequency and cumulative frequency distributions of the scalar shear, angular differences, and the vector shear are included, along with the corresponding 50, 90, 95, 97.5, and 99 percent values.

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I. INTRODUCTION

The data which will be presented in this report describes the deviation of the windspeed and direction from Berlin to Lindenberg, Germany, which are approximately 35 miles (56 km) apart. The monthly statistics form a unique data set because other research has consisted of deriving wind variation in terms of rectangular components (i.e., zonal and meridional windspeed), and because it is a long-term climatology of the horizontal wind variation. The literature review addresses the dominating theme of wind variability research that has appeared in the literature, including reference to other formulations of variability. In light of the attempt to relate temporal to spatial variations on a theoretical (Gage, 1979) and experimental (Jasperson, 1982) basis, temporal variability is briefly discussed.

In the final section spatial wind variability statistics are presented in monthly and seasonal summaries. The results show the frequency and cumulative frequency distributions of the windspeed differences (scalar shear), wind direction differences (angular differences), and vector shear at the following constant pressure levels: Surface, 1000 mb, 850 mb, 700 mb, and 500 mb. The corresponding 50, 90, 95, 97.5 and 99 percent values of the scalar shear, angular differences, and vector shear for each of the five constant pressure levels are also provided.

Some of the major results are the seasonal variation of the vector shear and angular differences between Berlin and Lindenberg. E.g., the 99 percent value of the vector shear between the two locations at the 500 mb level (approximately 5.5 km) is 21 knots for summer as compared to 44 knots for winter. The seasonal variation of the vector shear was found to be considerably less at the lower levels. At the 850 mb level (approximately 1.5 km), the 99 percent value of the vector shear averaged 22 knots, with a seasonal variation of 16 knots (summer) to 24 knots (fall). The angular differences were found to decrease with height. At 500 mb, the 95 percent values of the angular differences for the individual seasons were all near 35 degrees, whereas at 1000 mb (near the surface), the 95 percent value showed a variation of between 60 degrees (winter) and 90 degrees (summer).

II. MESOSCALE MODELLING

Mesoscale meteorology has received considerable attention over the past several years, and interest does not appear to have abated. Although deficiencies in our meteorological knowledge of the mesoscale have been acknowledged for some time, lack of financial resources have often been the limiting factor in gathering such data. Measurement techniques to accurately resolve spatial and temporal variations of meteorological quantities such as the three-dimensional wind field are very expensive and require specialized observing networks (e.g., Myrup et. al, 1982, Wendell, 1972, Young and Johnson, 1984; Shreffler, 1979, Olsen et. al, 1985, Ryan et al., 1985).

Mesoscale information is required for various goals, e.g., to refine synoptic scale numerical weather prediction models. Indeed, numerous high resolution models have been developed to forecast atmospheric motions on local scales (e.g., 30 to 300 km). Models to quantitatively predict precipitation (Perkey, 1976) and the onset of sea breezes (Pielke, 1974) have appeared in the literature. A non-hydrostatic model for mesoscale studies was introduced by Tapp and White (1976), and later used by Carpenter (1979) and Carpenter and Lowther (1981) to perform a sensitivity analysis of the initial conditions used in predicting the mesoscale wind field.

The mesoscale wind field has been singled out as the most important meteorological parameter in modelling air quality (Myrup et al., 1982). Diffusion meteorologists have devoted much of their attention to the repercussions of the vertical variation of the wind on atmospheric diffusion. In contrast, the horizontal variability of the mesoscale wind in the boundary layer has received considerably less study (Slade, 1968), despite analytical studies of atmospheric diffusion equations which show that the effect of wind-shear on horizontal dispersion becomes important beginning at least 5 km from the source (Tyldesley and Wallington, 1964). This is because micrometeorologists have often considered boundary-layer structures to be homogeneous in the horizontal, thus neglecting horizontal variability and therefore reducing the boundary-layer model to essentially an array of one-dimensional models without horizontal coupling (except that the boundary conditions are horizontally coupled). Barr and Kre'tzberg (1975) studied the role of horizontal variability in boundary-layer modelling by analyzing simple models in which surface-induced effects decrease exponentially with height as a function of horizontal wind, horizontal wave number of the surface irregularities, and the eddy diffusivity. Their analysis of a steady-state balance between horizontal advection and vertical diffusion demonstrated (quantitatively) how models with finer horizontal resolution improved resolution on the vertical scale, allowing for better predictions close to the surface. This may be useful in predicting mixing depths for air pollution warnings. Their model involves a passive scalar quantity and cannot be used to predict the orographic effects on the wind field.

III. MESOSCALE WIND FIELD

Diagnostic dynamical studies of the three-dimensional structure of frontal systems have revealed notable variations in structure, particularly parallel to the surface front. Roach and Hardman (1975) studied warm fronts and rainbands by deploying dropsondes every 30 km for about 300 km parallel to the surface warm front, the second near 2 km overriding the first at an angle of about 50 degrees. They identified a sloping band (approximately 1 in 200) 1 km deep of maximum direction shear roughly coinciding with maximum windspeed in the lower portion of the warm frontal zone. The low-level jet marks an apparent transition between a predominantly westerly flow and southerly current of cold air ahead of the warm front. This was inferred from their Fig. 4, in which a westerly jet of 27 m/sec^{-1} between 1.5 and 2.0 km lies above a southerly jet of maximum windspeeds in the vicinity of 0.6 km.

James and Browning (1979) evaluated the mesoscale structure of line convection at surface cold fronts on scales ranging from several km to over 100 km. Most often the line convection is broken into variable size elements separated by smaller gaps, as opposed to a simple two-dimensional structure. The passage of a line element usually consists of brief downpours, a drop in temperature and windspeed, sudden change in wind direction, and pressure jumps. The elements were found to disintegrate and then merge together again on time scales of a few minutes to a few hours. The authors highlighted certain common features of the line elements, e.g., that they are always oriented slightly clockwise with respect to the surface cold front. Elements of different sizes, however, moved in the same direction with a component parallel to the front in the direction of the low-level jet which occurred ahead of the front. One of the consequences of line convection is often strong horizontal shear as large as 10^{-2} sec^{-1}, e.g., a change of 25 m/sec^{-1} over 2.5 km, which is important to those concerned with the dynamics of low-level flight. James Browning (1979) lists the maximum vector wind shear observed as elements passed over anemometers at 10 m to range from 0.3 to 1.2×10^{-2} sec^{-1}.

Attention is called that the unit second^{-1} used for wind-shears can be misleading. As pointed out by Essenwanger (1963) no linear transformation from one shear interval (horizontal or vertical) is valid.

The passage of a shallow cold front over complex terrain was analyzed by Young and Johnson (1984) using a surface mesonetwork of 22 stations (spaced approximately 40 km apart) and the National Oceanic and Atmospheric Administration (NOAA) Boulder Atmospheric Observatory (BAO) tower, which was instrumented with sonic anemometers at 8 levels up to 300 m. Eddies formed in the lee of topographic barriers while other portions of the front escaped across the eastern plains, including a passage of the cold front from the east at some stations. Time-height cross-sections of u- and w- wind components at the BAO lower are presented, supplemented by a horizontal space scale. Their time-to-space conversion was based on a frontal speed of approximately 10 m/sec^{-1} in a direction perpendicular to the front as derived from the mesonetwork. A current of cold air at 50 to 100 m overtaking the front from behind, essentially wedged in between the surface friction layer and the turbulent layer within the frontal zone, were identified by Young and Johnson (1984) as features similar to atmospheric gravity currents. The transition between syn-optic-scale air masses can occur on space and time scales as small

as 100 m and 10 sec, respectively. These phenomena (microscale turbulence, strong windshears) are beyond the resolution capabilities of synoptic-scale networks.

Nappo (1977) analyzed the mesoscale wind field over complex terrain during the Eastern Tennessee Trajectory Experiment, a study motivated by the interest in the long-range transport and diffusion of sulfates in the East. The decrease in plume concentration over complex terrain has been partially attributed to horizontal wind variability. The data in this study were obtained from a combination of meteorological towers and single-theodolite pilot balloon wind soundings. Nappo (1977) concluded that during stable conditions the variability was substantial and strongly influenced by the terrain, while during unstable conditions the variability was considerably less.

One interesting facet of the urban effects on weather is the difference in urban and rural winds. This lively discussion has often centered around Project METROMEX, a study which addressed mesoscale wind differences in the St. Louis, Missouri, area. Wong and Dirks (1978) used aircraft data to portray the wind field at 450 m on three summer afternoons. Their data apparently supports the hypothesis of wind accelerating towards the city under a strong heat island accompanied by light winds which are below a threshold value, and wind accelerating away from the city under weaker heat island with strong winds.

Earlier Project METROMEX case studies (Spangler and Dirks, 1978) examined the variations of moisture and temperature inversion height in the metropolitan St. Louis area by acquiring aircraft, lidar, pilot balloon, and radiosonde data. However, only the average low-level winds and average winds above the inversion layer for the region are mentioned, and horizontal wind variability is not discussed.

A study known as the Regional Air Monitoring System (RAMS), a network of 17, 30 m towers, was also performed in the St. Louis region to elucidate differences between urban and rural windspeed and direction. Shreffler (1979) examined these data and found that for strong heat islands, the rural windspeed always exceeds the urban windspeed, whereas only under a weak heat island and nearly calm winds (windspeed less than 1.5 m/sec) was the urban windspeed somewhat higher. This result caused Shreffler (1979) to cast doubt on the concept of a generalized critical mesoscale windspeed (below which windspeed is higher in the city).

IVA. SPATIAL WIND VARIABILITY

Although wind variability has primarily been discussed on the synoptic scale (i.e., hundreds of kilometers), a number of researchers have concerned themselves with mesoscale wind variability. Gabriel and Bellucci (1951) using double theodolites and Plagge and Smith (as reported in Ellsaesser, 1969) using GMD 1-a rawins and SCR-584 radars during the mid-50's studied time variability on an hourly basis. Within the last several years, data available from the METRAC system (Gage and Jasperson, 1979, Jasperson, 1982a and b) and the 40 MHz Sunset radar (Gage and Clark, 1978) have been used to evaluate wind variability over time. Spatial wind variability, which is the topic of this report, has been studied by Danard (1965), Lenhard (1973), and Jasperson (1982), on spatial scales out to 48 km, 16.25 km, and 20.9 km, and 20.9 km, respectively. In addition, Nappo (1977) reported area-averaged statistics of horizontal wind variability for a network of stations contained within a 200 km by 160 km area. (The distance between the two stations in the present study is approximatley 56 km.)

One of Nappo's measure of horizontal variability was the standard deviation of the horizontal windspeed and wind direction from the area-overaged speed and direction, respectively. The area-average wind direction is defined as:

$$\theta = \tan^{-1}(U/V) \qquad (1)$$

where U and V are the area-averaged values of the U and V components of the wind velocity. However, Nappo found more useful an analysis of the spatial mean and eddy component of the mesoscale wind field (vertical profiles formed from the horizontally averaged windspeed and direction), in which the wind components are decomposed into a mean and deviation from the mean (eddy value):

$$\text{Mean Kinetic Energy} = \text{MKE} = 1/2\ (\overline{U}^2 + \overline{V}^2) \qquad (2)$$

$$\text{Eddy Kinetic Energy} = \text{EKE} = 1/2\ (\overline{U^2 + V^2}) - \text{MKE} \qquad (3)$$

where the overbar indicates a horizontal average. In particular, EKE is produced by horizontal variations in wind direction in addition to windspeed, and will decrease with increasing height. The ratio EKE/MKE for unstable periods average 0.07 (vertical average of different heights) increasing to 0.38 during stable periods.

Wind variability research has centered around elucidating the dependence of variability on space and time lags. These studies have appealed to G.I. Taylor's statistical theory of turbulence and formulate the variability S as:

$$S = KQ^P \qquad (4)$$

where Q is either time or distance and K is a constant. Lenhard (1973) chose P = 1/2 based on Durst's (1954) original model which assumed that the Eulerian autocorrelation function, i.e., the model for the decay of the correlation with time was of the form:

$$r(t) = e^{-at} \qquad (5)$$

where $a = 6.9 \times 10^{-6}\ sec^{-1}$ was chosen by Durst so that a variation of 3 hours was equivalent to a 50 nautical mile separation.

Temporal wind variability (see section 4B), which has received more attention in the literature than spatial wind varability, may be defined as:

$$\sigma_T = \overline{([U(t) - U(t + \Delta t]^2)^{1/2}} \qquad (6A)$$

The time structure function for the U component of velocity in stationary turbulence is:

$$\sigma_T^2 = 2\ (U')^2\ (1-r(t)) = D(t) \qquad (6B)$$

where $U' = U-\overline{U}$. Note that D(t) will be proportional to the square root of t, implying P = 1/2.

By considering a theoretical two-dimensional inertial range model ("5/3 law"), it was demonstrated by Gage (1979) that the structure function D(t) is proportional to $t^{2/3}$ within the inertial subrange. Therefore the variability, which is proportional to the square root of the structure function, will follow $t^{1/3}$. Gage started with the structure function in space and derived the structure function in time. This was accomplished by applying Taylor's transformation (also known as the frozen turbulence hypothesis) to the expression for temporal variability, as derived from the $^{-5/3}$ law. According to the Taylor transformation, the turbulent structure will be frozen as it is advected past a sensor with the velocity of the mean flow. Gage essentially provided evidence for the existence of a two-dimensional, reverse-cascading energy inertial range based on the results of wind variability studies.

Lenhard (1973) evaluated Arnold and Bellucci's (1957) formulation for the local observed variability S_d.

$$S_d = 0.53\ d^{\ 1/2} \qquad d : km,\ S_d : meters/second \qquad (7)$$

where d is the distance between the two stations. The total observed variability, which may be found from:

$$\begin{aligned}(nS_d)^2 = n\sum(U_i - U_{i+d})^2 - \left[\sum(U_i - U_{i+d})\right]^2 + \\ n\sum(V_i - V_{i+d})^2 - \left[\sum(V_i - V_{i+d})\right]^2\end{aligned} \qquad (8)$$

was calculated by Lenhard (1973) for 41 pairs of simultaneous GMD radiosonde flight over a distance of 16.25 km. The variability was approximately constant up to 6 km (ranging from 3 to 4 meters per second) and then consistently increasing at higher levels. In this study, the vector mean windspeed and S_d as a function of height were plotted. The vector mean windspeed was found by averaging the wind components for all flights from both locations, and the standard vector deviation was computed by averaging the component standard deviations. Also, by knowing d and evaluating S_d from the data, K (see Eq. (4)) was shown to increase from 0.6 at the surface to 2.0 at 9 km. K increased with increasing S as well as increasing windspeed, and the correlation of 0.81 was obtained from the linear regression of K on windspeed.

Another way to formulate the variability is:

$$S = \sigma_1^2 + \sigma_2^2 - 2r_{1\ 2}\ \sigma\ _1\sigma_2 \qquad (9)$$

where S is the variability, σ_1 and σ_2 are the standard vector deviation of the two data sets with correlation (i.e., statistical variance formula for autocorrelation) r_{12}.

For time variability, autocorrelation, where $\sigma_1 = \sigma_2$

$$S_t^2 = 2\ \sigma^2(1 - r_t) \qquad (10)$$

Danard (1965) called S_t the "true variability", where r_t is the stretch vector correlation. Referring to Eq. (5), Lenhard (1973) estimated r_d from:

$$r_d = e^{-at} \qquad (11)$$

and used this value to compute an estimated variability S^*,

$$S^* = 2\ \sigma^2(1 - r_d) \qquad (12)$$

where σ is the standard vector deviation, and r_d is the linear correlation coefficient of the windspeed between the two data sets (separated by a distance of 16.25 km in this case). This estimate was lower than the actual S_d up to 5 km. Durst's model is that the variation at 3 hours is equivalent to a 50 nautical mile separation (which accounts for the constant a). Therefore by knowing the spatial separation, the equivalent time in seconds is then substituted into Eq. (11) to obtain an estimate for r_d (see section 5).

IVB. TEMPORAL WIND VARIABILITY

Gifford (1956) constructed Kolmogorov structure functions for longitudinal and transverse components of isotropic turbulence and concluded that time variability of the wind will follow $t^{1/3}$. Taylor (1957) in evaluating boundary-layer wind data and Hutchings (1955) in evaluating 6-hour 500 mb data both found justification for a $t^{1/3}$ law. Ellsaesser (1969) cites Gifford's theoretical findings and empirical data obtained by Plagge and Smith during the 1950's in concluding that the $t^{1/3}$ law is more appropriate than the $t^{1/2}$ law, particularly for lag periods of up to 6 hours. Ellsaesser (1969) discussed other sources of time variability data that were available at that time, but the lack of homogeneity in each of these data sets precluded drawing any conclusions.

Billions (1973) analyzed hourly wind data collected by Air Force Cambridge Reseach Laboratory over a 7-day period using polynomial analysis (see Essenwanger, 1973). In this method, the autocorrelations of windspeed, wind component (zonal and meriodional), and wind direction characteristic coefficients (surface to 1 km) as a function of lag time from 0 to 24 hours were obtained.

The pulsed Doppler radar is a more recent tool for constructing a climatology of mesoscale wind variability because of its ability to rapidly sample the wind. Shapiro et al. (1984), reported on the NOAA Wave Propagation Laboratory VHF wind profiler observations of mesoscale wind systems in Colorado. The resolution capabilities of the profiler are 100 m resolution from just above 1/4 km to 2 1/2 km above ground level (AGL), and 300 m resolution from 1 1/2 km to over 8 1/2 km. Their study illustrates the enormous potential to obtain data on the vertical and horizontal scale, the approximate temporal structure of fronts, and associated jet stream characteristics. Gage and Clark (1978) utilized VHF Doppler radar to sample the three-dimensional field once per minute for 14 hours at altitudes ranging from 5 to 13 km at 1 km intervals. Although the average variability followed a 1/3 power law to 4 hours, this power varied somewhat with height. The improved depiction and numerical prediction of mesoscale weather events, particularly to forecast the intensification of fronts over time and the subsequent development of precipitation systems, is one of the motivations behind this type of study.

Gage and Jasperson (1979) analyzed wind variability below 5 km over 100 m intervals for time lags of 30 minutes to 3 hours as measured by the METRAC balloon-tracking system. The average temporal variability was also found to be consistent with a $^{1/3}$ power law, but the temporal variability at the individual altitudes also showed substantial variation. In another study using the METRAC system (Jasperson, 1982a), the average time variability of the wind for "anticyclonic weather patterns" followed a $^{1/3}$ power law, but for "cyclonic patterns" (frontal passages) was more nearly $^{1/2}$.

Spatial variability of 0.990 m/sec^{-1}, 1.741 m/sec^{-1}, and 2.446 m/sec^{-1} was determined by Jasperson (1982) for launch point separations of 20 m (910 observations), 4.415 km (3116 observations), and 20.910 km (801 observations). Jasperson refrained from deriving a power law relating the spatial variability to spatial separation because the data for each launch point separation were obtained on different days under markedly different weather conditions.

However, Jasperson (1982) also provided unique data on the differences between the time variability as computed at a single station, and the "space-time" variability, which is the variability computed for a pair of stations separated by a certain distance (in this case 20m, 4.415 km, and 20.910 km), in which the balloon is launched from the second location at some later time (from 30 to 24 minutes later at a time lag of 30 minutes). The increased variability due to space variability is evident in the differences between time and space-time variability. At a time lag of 30 min, these differences are 0.02, 0.047, and 0.62 m/sec^{-1} at a separation of 20 m, 4.415 km, and 20.910 km, respectively. For the 20.910 km separation, the difference oscillates about a value of 0.10 m/sec^{-1} for the time lags of 90 minutes or longer. The fact that this difference does not rapidly approach 0 indicates that there are detectable spatial features of the wind field. From these data, Jasperson derived an equivalent time lag of 17 minutes for a spatial separation of 4.415 km and a time lag of 90 minutes for a spatial separation of 20.910 km.

Olsen et al. (1985), also studied both temporal and spatial variability for an area 30 km by 20 km by analyzing data from radiosonde release. These data were obtained as the initial phase of a wind variability study for the MLRS System. Due to the sparseness of the data (only 8 data sets) and the light prevailing winds, neither power law relationships nor space-time equivalents were derived.

Morone (1986) studied horizontal wind variability as a function of distance by computing structure functions (the square of the difference in windspeeds between two locations) from winds measured by inertial navigation systems on jet aircraft. The structure functions were computed over separation distances that varied up to 500 km and were sorted according to separation distance into 20 intervals of 25 km each. Some of the structure functions were computed over approximately the same interval as the distance between the two stations studied in this report. However, most of these data were collected at an altitude of 9.5 to 10.5 km, well above the region of interest in this report. Coupled with the restriction that windspeeds must be less than or equal to 20 m/sec^{-1}, these structure functions were therefore computed away from regions of strong horizontal shear (i.e., strong jets). Strictly speaking, these structure functions are indicative of space-time variability, as the wind reports may be separated by three hours. (The assumption that the structure functions are only a function of distance appears to be justified at the 10 km altitude.)

V. WIND VARIATION DATA

The data presented in these sections consists of the wind variability and wind-shear in the horizontal for two stations within close proximity, Berlin and Lindenberg (56 km apart), calculated at the same pressure level. An examination of the difference in geopotential height between Berlin and Lindenberg at the 850 and 700 mb pressure levels for four selected months in 1977 revealed mean differences ranging from 6.5 m (April) to 10.3 m (October) at the 850 mb level and 7.9 m (April) to 13.2 m (October) at the 700 mb level. An approximation is made that the altitude (geometric height) of the two pressure levels will be the same for simultaneous observations. The horizontal differences are a measure of the mesoscale spatial wind variability at the indicated altitudes. (It should be noted that geopotential heights of 1500 m, 3000 m, and 5500 m correspond to geometric heights of 1504.5 m, 3009 m, and 5516 m for this location.) The height of the individual pressure levels, of course, fluctuate on a day-to-day basis.

The following analysis is due to Essenwanger (1974). For a derivation of Eqs. (15) and (16), see Appendix A.

By considering V_1, θ_1, V_2, and θ_2 to be windspeed and direction at Lindenberg and Berlin, respectively, the following wind difference parameters and wind-shear components were calculated at the surface, 1000 mb, (close to surface), 850 mb (approximately 1.5 km), 700 mb (approximately 3 km), and 500 mb (approximately 5.5 km):

$$V_s = V_2 - V_1 \tag{13}$$

$$\Delta\theta = \theta_2 - \theta_1 \quad , \left|\Delta\theta\right| \leq 180 \text{ degrees} \tag{14}$$

$$\Phi_s = 2\sqrt{V_1 V_2}\,\sin(\Delta\theta/2) \tag{15}$$

$$S = \sqrt{V_s^2 + \Phi_s^2} \tag{16}$$

The wind-shear components V_s and Φ_s were combined vectorially to determine the wind-shear S. The wind-shear represents the deviation of the windspeed and direction from one measurement location to another.

The period of record for the data that are discussed in this report is 1974-78 and 1981. These data were extracted from teletype messages intercepted in this office and placed on punch cards for computer analysis. All observations were taken at 1200 Greenwich Mean Time (GMT). This represents the best data set that we have available. The data have been stratified according to month and season and totaled for the year (See Table 1B).

Tables 2 through 16 list the percent and cumulative percent occurrence of windspeed differences in 3-knot intervals as well as the 50, 90, 95, 97.5, and 99 percentile values of the differences in windspeed for the 5 individual altitude levels. As anticipated, the windspeed differences tend to increase with height. For example, the percent occurrence of differences in windspeed less than or equal to 5 knots decreases considerably from 92 percent at the surface to 76 percent at 850 mb for all observations pooled together. At 500 mb, wind-speed differences of 6 to 11 knots occur with a frequency of nearly

22.5 percent on an annual basis. Considering the individual months only, this per-centage ranges from 15 percent in June to nearly 33 percent in January.

At the surface and 1000 mb (near surface), the 90th percentile ranges from 4 to 7 knots with an annual range of 4.8 knots for the windspeed, while the 99th percentile shows values mostly over 8 knots with an annual average of 12.2 knots at the surface and 9.7 knots at the 1000 mb level. The differences are higher at 850 mb, between 8 and 12 knots for 90th percentile, and mostly over 12 knots for the 99th percentile (annual average 15.1 knots). For some individual months the 99th percentile displays very high differences such as 17 knots in January, 22 knots in September, or 25.1 knots in December at the 850 mb level. These fluctuations between the months may be attributed to various factors such as the limitation of the period of record, frontal passage at one station and not yet at the other, and observational or instrumental errors. However, the seasonal trend is adequately reflected in the seasonal tabulations.

The wind variability S_d was computed for each of the pressure levels using Eq. (8), and these results are listed in Table 17. The wind variability was found to generally increase with height, a result consistent with the findings of other authors (Danard 1965, Lenhard 1973, and Jasperson 1982). Lenhard's data indicated an increase in variability from 5.5 knots at 1.5 km to nearly 8 knots at 3 km, decreasing slightly at 5.5 km before increasing with height again. In the current study, the variability decreased slightly from 7.87 knots at 1.5 km to 7.13 knots at 3 km before increasing to 9.35 knots at 5.5 km. The larger variability in this study is not surprising due to the increased distance between stations (Lenhard's data contained only 41 observations spaced 16.25 km apart). An average variability of 7.20 knots (averaging all of the individual variabilities listed in Table 17) compares well with a variability of 7.71 knots which is obtained by substituting d = 56 km into Eq. (7).

Using Durst's model (Eq. (5)) for estimating r_d does not reflect the rapid increase in correlation with height due to the decreasing effect of the friction layer (Table 17). The average r_d = 0.827 implies considerably more variability than r_d = 0.956 as derived from Durst's model. The predicted r_d = 0.956 was obtained by finding a time equivalent in seconds for 56 km from the relationship 3 hours = 50 nmi, and substituting this value of t into Eq. (11).

Tables 18 through 32 list the percent and cumulative percent occurrence of wind direction differences between Berlin and Lindenberg in 30-degree intervals as well as the 50, 90, 95, 97.5, and 99 percentile values of the differences in wind direction for the 5 individual altitude levels. Overall, differences in wind direction of greater than or equal to 60 degrees occurred with a frequency of 5 percent at 850 mb, decreasing to 3.75 percent at 700 mb, and 2.75 percent at 500 mb. The effect of the friction layer at the surface is evident from these data as differences in wind direction are smaller at 850 mb (approximately 1500 meters) than at or near the surface. Considering the month of July as an extreme case, the percent occurrence of wind direction differences of less than or equal to 29 degrees increase dramatically from 67 percent at the surface to 90 percent at 850 mb.

In 50 percent of the cases the difference in direction is 20 degrees or less at and near the surface, and 15 degrees at 850 mb. The 90th percentile difference in wind direction decreases from 55 degrees at the surface to 35 degrees at 850 mb. Similarly, the 95th percentile difference in wind direction decreases from 75 degrees at the surface to 55 degrees at 850 mb. Also, the 99th percentile difference in wind direction decreases from 130 degrees at the surface to 100 degrees at 850 mb. The 95th percentile of the difference in wind direction between the two stations ranges from 35 degrees in December to 140 degrees in June. This decrease toward the upper levels is due to the decreasing influence of the friction in the boundary layer.

Tables 33 through 47 contain the percent and cumulative percent occurrence of wind-shear (as defined in (16)) between Berlin and Lindenberg in 3-knot intervals as well as the 50, 90, 95, 97.5, and 99 percentile values of the shear for the 5 individual altitude levels. A shear of less than or equal to 8 knots occurred with a frequency of 73 percent in winter increasing to 87 percent in summer. Similar increases in shear during winter were noted for all altitudes above the friction layer. A shear of 12 to 14 knots occurs with a frequency of 0.5 percent near the surface, increasing to 2.5 percent at 850 mb, and 5 percent at 700 mb. A seasonal trend towards increasing shear during fall and winter is evident, as windspeeds generally increase more rapidly with altitude in winter. This phenomena may be attributed to the difference in the slope of cold and warm fronts. The latter is considerably smaller, thereby producing smaller wind-shears. Large frontal slopes (cold fronts) are associated with the well developed synoptic systems which typically occur in winter. The largest percentage of small shear in the lowest levels (at or near the surface) occurred during winter, supporting the hypothesis of decreased variability during unstable conditions in the boundary layer (Nappo, 1977).

VI. SUMMARY AND CONCLUSIONS

Wind variability and wind-shear in the horizontal for two stations in Germany that are 35 miles apart were calculated at the same pressure level. A literature search revealed that very little data concerning wind variability over 30 to 50 miles is available. Previous studies do not take into account the direction contribution to the wind-shear, as other authors have analyzed the rectangular components only.

Previous studies report on data obtained from specialized networks. However, Berlin and Lindenberg, which both report upper-air observations are only 35 miles (56 km) apart, which has provided an opportunity to create a long-term climatology of mesoscale wind variability.

Open literature publications briefly mention wind variability as a function of atmospheric stability. The TVA study (Nappo, 1977) provided the most evidence that wind variability was high during stable conditions and low during unstable conditions (above the surface). Essenwanger and Stewart (1983) found that the atmosphere was unstable more often than neutral for morning observations taken at 1200 GMT at Frankfurt and Hahn, Germany. Because the data in this report comprises observations taken at 1200 GMT only, it is possible that the diurnal wind variability has been underestimated. Therefore a further study of wind-shear as a function of atmospheric stability utilizing both morning and evening observations would be of interest. Further studies in this area are relevant because previous models that approximate wind variability as a function of distance appear to be inadequate.

TABLE 1A. The Mean And Standard Deviation (In Parentheses) Of The Difference In Geopotential Height Between Berlin And Lindenberg At The 850 And 700 Millibar Pressure Levels For 4 Selected Months In 1977

	850mb	700mb
January	7.8 (4.7)	8.1 (5.3)
April	7.0 (9.1)	7.9 (6.5)
July	8.8 (5.6)	10.6 (8.3)
October	9.8 (8.1)	13.2 (11.9)

TABLE 1B. The Number of Observations According To Month and Season. All Observations Were Recorded At 1200 GMT For The Period Of 1974-78, 1981

Month	Number of Observations
January	95
February	101
March	108
April	115
May	112
June	86
July	91
August	105
September	135
October	135
November	117
December	89
Fall	387
Winter	285
Spring	335
Summer	282
Total	1289

TABLE 2. Percent Occurrence Of The Differences In Windspeed (Knots), Berlin And Lindenberg, At The Surface, 1200 Hours GMT (1974-78, 1981)

	0 TO 2	3 TO 5	6 TO 8	9 TO 11	12 TO 14	GT 15
JANUARY	68.42	25.26	5.26	0.00	0.00	1.05
FEBRUARY	64.36	32.67	2.97	0.00	0.00	0.00
MARCH	64.31	28.70	5.56	.93	0.00	0.00
APRIL	58.26	34.78	6.96	0.00	0.00	0.00
MAY	65.18	26.79	6.25	0.00	0.00	1.79
JUNE	55.81	29.07	12.79	0.00	2.33	0.00
JULY	61.54	25.27	9.89	2.20	0.00	1.10
AUGUST	66.67	25.71	5.71	0.00	0.00	1.90
SEPTEMBER	58.52	33.33	7.41	.74	0.00	0.00
OCTOBER	71.11	25.19	2.96	.74	0.00	0.00
NOVEMBER	59.83	34.19	3.42	0.00	.85	1.71
DECEMBER	55.06	37.08	6.74	0.00	0.00	1.12
FALL	63.31	30.75	4.65	.52	.26	.52
WINTER	62.31	31.98	4.91	0.00	0.00	.70
SPRING	62.69	30.15	6.27	.30	0.00	[illegible]
SUMMER	61.70	25.60	9.22	.71	.71	1.06
ANNUAL	62.58	29.57	6.13	.34	.25	.73

TABLE 3. Cumulative Percent Occurrence Of The Differences In Windspeed (Knots), Berlin and Lindenberg, At The Surface, 1200 Hours GMT (1974-78, 1981)

	0 TO 2	3 TO 5	6 TO 8	9 TO 11	12 TO 14	GT 15
JANUARY	68.42	93.68	98.95	98.95	98.95	100.00
FEBRUARY	64.36	97.03	100.00	100.00	100.00	100.00
MARCH	64.81	93.52	99.07	100.00	100.00	100.00
APRIL	58.26	93.04	100.00	100.00	100.00	100.00
MAY	65.18	91.96	98.21	98.21	98.21	100.00
JUNE	55.31	94.38	97.67	97.67	100.00	100.00
JULY	61.54	95.51	96.70	98.90	98.90	100.00
AUGUST	66.67	92.38	98.10	98.10	98.10	100.00
SEPTEMBER	59.52	91.35	99.25	100.00	100.00	100.00
OCTOBER	71.11	[illegible]	99.26	100.00	100.00	100.00
NOVEMBER	59.83	94.02	97.44	97.44	98.29	100.00
DECEMBER	55.06	92.13	98.30	[illegible]	98.85	100.00
FALL	63.31	[illegible]	98.71	99.22	99.45	100.00
WINTER	[illegible]	94.39	[illegible]	[illegible]	99.50	100.00
SPRING	62.59	[illegible]	[illegible]	[illegible]	99.40	100.00
SUMMER	61.70	93.39	97.52	[illegible]	98.94	100.00
ANNUAL	[illegible]	92.55	[illegible]	99.07	99.30	100.00

TABLE 4. 50, 90, 95, 97.5, And 99 Percentile Values Of The Differences In Windspeed (Knots), Berlin And Lindenberg, At The Surface, 1200 Hours GMT (1974-78, 1981)

	50TH PERC	90TH PERC	95TH PERC	97.5 PERC	99TH PERC
JANUARY	2.0	4.5	6.3	7.4	8.0
FEBRUARY	2.0	4.0	5.0	5.9	8.0
MARCH	2.0	5.0	7.0	7.0	8.0
APRIL	2.0	5.0	6.0	7.1	8.0
MAY	2.0	5.0	6.0	7.0	17.8
JUNE	2.0	6.0	8.0	8.5	12.0
JULY	2.0	6.0	7.4	10.0	10.0
AUGUST	2.0	5.0	7.0	7.4	23.0
SEPTEMBER	2.0	5.0	6.3	7.0	8.1
OCTOBER	2.0	4.0	5.0	6.0	7.8
NOVEMBER	2.0	4.0	6.0	7.0	35.0
DECEMBER	2.0	5.0	6.5	7.0	8.3
WINTER	2.0	5.0	6.0	7.0	8.0
SPRING	2.0	5.0	6.0	7.0	8.4
SUMMER	2.0	6.0	7.1	8.0	14.0
FALL	2.0	4.0	6.0	7.0	10.1
ANNUAL	2.0	5.0	6.0	7.0	10.1

TABLE 5. Percent Occurrence Of The Differences In Windspeed (Knots), Berlin and Lindenberg, At 1000 Millibar, 1200 Hours (1974-78, 1981)

	0 TO 2	3 TO 5	6 TO 8	9 TO 11	12 TO 14	GT 15
JANUARY	53.68	30.53	8.42	7.37	0.00	0.00
FEBRUARY	52.48	37.62	5.94	1.98	0.00	1.98
MARCH	56.48	33.33	8.33	1.85	0.00	0.00
APRIL	53.04	39.13	6.96	.87	0.00	0.00
MAY	58.04	33.93	7.14	0.00	0.00	.89
JUNE	53.49	31.40	11.63	1.16	2.33	0.00
JULY	50.55	36.26	9.89	3.30	0.00	0.00
AUGUST	52.38	37.14	8.57	1.90	0.00	0.00
SEPTEMBER	54.81	33.33	8.89	.74	.74	1.48
OCTOBER	56.30	37.04	5.19	1.48	0.00	0.00
NOVEMBER	47.01	38.46	11.97	1.71	.85	0.00
DECEMBER	51.69	40.45	4.49	2.25	0.00	1.12
FALL	52.97	36.18	8.53	1.29	.52	.52
WINTER	52.63	36.14	6.32	3.86	0.00	1.05
SPRING	55.82	35.52	7.46	.90	0.00	.30
SUMMER	52.13	36.11	8.93	2.13	.71	0.00
ANNUAL	53.45	35.76	8.07	1.94	.31	.47

TABLE 6. Cumulative Percent Occurrence Of The Differences In Windspeed (Knots), Berlin And Lindenberg, At 1000 Millibar, 1200 Hours GMT (1974-78, 1981)

	0 TO 2	3 TO 5	6 TO 8	9 TO 11	12 TO 14	GT 15
JANUARY	53.68	84.21	92.63	100.00	100.00	100.00
FEBRUARY	52.48	90.10	96.04	98.02	98.02	100.00
MARCH	56.48	89.31	98.15	100.00	100.00	100.00
APRIL	53.04	92.17	99.13	100.00	100.00	100.00
MAY	58.04	91.96	99.11	99.11	99.11	100.00
JUNE	53.49	84.88	96.51	97.67	100.00	100.00
JULY	50.55	86.31	96.70	100.00	100.00	100.00
AUGUST	52.38	89.52	98.10	100.00	100.00	100.00
SEPTEMBER	54.81	88.15	97.04	97.78	98.52	100.00
OCTOBER	56.30	93.33	98.52	100.00	100.00	100.00
NOVEMBER	47.01	85.47	97.44	99.15	100.00	100.00
DECEMBER	51.69	92.13	96.63	98.88	98.88	100.00
FALL	52.97	89.15	97.67	98.97	99.43	100.00
WINTER	52.63	88.77	95.39	98.95	98.95	100.00
SPRING	55.82	91.34	98.81	99.70	99.70	100.00
SUMMER	52.13	87.23	97.16	99.23	100.00	100.00
ANNUAL	53.45	89.22	97.33	99.22	99.55	100.00

TABLE 7. 50, 90, 95, 97.5, And 99 Percentile Values Of The Differences In Windspeed (Knots), Berlin And Lindenberg, At 1000 Millibar, 1200 Hours GMT (1974-78, 1981)

	50TH PERC	90TH PERC	95TH PERC	97.5 PERC	99TH PERC
JANUARY	2.0	7.0	9.0	10.0	10.0
FEBRUARY	2.0	5.2	8.0	9.0	25.0
MARCH	2.0	5.2	7.0	7.3	9.0
APRIL	2.0	5.0	6.0	7.0	8.2
MAY	2.0	5.0	6.0	7.0	9.2
JUNE	2.0	6.0	7.3	8.5	12.0
JULY	2.0	6.0	8.0	10.0	10.0
AUGUST	2.0	5.5	6.3	7.4	9.0
SEPTEMBER	2.0	6.0	7.0	11.8	15.4
OCTOBER	2.0	5.0	6.0	7.0	9.0
NOVEMBER	3.0	6.0	7.0	8.0	10.5
DECEMBER	2.0	5.0	6.9	9.0	10.1
WINTER	2.0	6.0	8.3	9.0	11.3
SPRING	2.0	5.0	6.3	7.0	9.0
SUMMER	2.0	6.0	7.1	9.0	10.2
FALL	2.0	6.0	7.0	7.3	11.3
ANNUAL	2.0	6.0	7.0	9.0	10.0

TABLE 8. Percent Occurrence Of The Differences Of The Windspeed (Knots), Berlin And Lindenberg, At 850 Millibar, 1200 Hours GMT (1974-78, 1981)

	0 TO 2	3 TO 5	6 TO 8	9 TO 11	12 TO 14	GT 15
JANUARY	28.42	34.74	11.58	13.68	5.26	6.32
FEBRUARY	41.58	38.61	12.87	2.97	3.96	0.00
MARCH	44.44	26.35	15.74	7.41	2.78	2.78
APRIL	53.91	25.22	13.04	3.48	.87	3.48
MAY	44.64	35.71	12.50	5.36	.89	.89
JUNE	52.33	31.40	12.79	2.33	1.16	0.00
JULY	39.56	42.86	12.09	3.30	2.20	0.00
AUGUST	47.62	36.19	10.48	1.90	3.31	0.00
SEPTEMBER	37.78	37.04	14.07	8.15	.74	2.22
OCTOBER	48.89	27.41	14.81	2.96	4.44	1.48
NOVEMBER	36.75	31.62	15.38	9.40	5.98	.85
DECEMBER	35.96	29.21	17.98	4.49	3.37	8.99
FALL	41.34	32.04	14.73	5.72	3.62	1.55
WINTER	35.44	34.39	14.04	7.12	4.21	4.91
SPRING	47.76	29.25	13.73	5.37	1.49	2.39
SUMMER	46.45	36.38	11.70	2.45	2.46	0.00
ANNUAL	42.32	32.39	13.55	5.51	2.95	2.27

TABLE 9. Cumulative Percent Occurrence Of The Differences In Windspeed (Knots), Berlin And Lindenberg, At 850 Millibar, 1200 Hours GMT (1974-78, 1981)

	0 TO 2	3 TO 5	6 TO 8	9 TO 11	12 TO 14	GT 15
JANUARY	28.42	63.16	74.74	88.42	93.68	100.00
FEBRUARY	41.58	80.20	93.07	96.04	100.00	100.00
MARCH	44.44	71.30	87.04	94.44	97.22	100.00
APRIL	53.91	73.13	92.17	95.65	96.52	100.00
MAY	44.64	80.36	92.86	93.21	99.11	100.00
JUNE	52.33	83.72	96.51	98.84	100.00	100.00
JULY	39.56	82.42	94.51	97.80	100.00	100.00
AUGUST	47.62	83.31	94.29	96.19	100.00	100.00
SEPTEMBER	37.78	74.81	88.89	97.04	97.78	100.00
OCTOBER	48.89	75.30	91.11	94.07	98.52	100.00
NOVEMBER	36.75	68.38	83.76	93.16	99.15	100.00
DECEMBER	35.96	65.17	83.15	87.64	91.01	100.00
FALL	41.34	73.39	88.11	94.33	98.45	100.00
WINTER	35.44	69.32	83.86	90.88	95.09	100.00
SPRING	47.76	77.01	90.75	94.12	97.61	100.00
SUMMER	46.45	83.33	95.04	97.52	100.00	100.00
ANNUAL	42.82	75.72	89.37	94.33	97.33	100.00

TABLE 10. 50, 90, 95, 97.5, And 99 Percentile Values Of The Differences In Windspeed (Knots), Berlin And Lindenberg, At 850 Millibar, 1200 Hours GMT (1974-78, 1981)

	50TH PERC	90TH PERC	95TH PERC	97.5 PERC	99TH PERC
JANUARY	4.0	12.0	15.0	17.0	17.0
FEBRUARY	3.0	7.0	9.0	12.0	12.0
MARCH	3.0	9.0	12.4	14.3	18.0
APRIL	2.0	7.0	10.0	15.0	15.3
MAY	3.0	7.2	9.4	11.0	13.4
JUNE	2.0	6.4	7.3	9.2	10.6
JULY	3.0	7.1	8.4	11.6	13.0
AUGUST	3.0	6.0	9.0	12.4	13.0
SEPTEMBER	3.0	9.0	10.0	11.4	22.0
OCTOBER	3.0	8.0	12.0	14.0	16.4
NOVEMBER	3.5	11.0	12.2	13.0	16.2
DECEMBER	4.0	12.0	17.5	20.2	21.5
WINTER	4.0	11.0	14.3	17.0	20.2
SPRING	3.0	8.0	11.0	14.4	16.4
SUMMER	3.0	7.0	3.1	11.0	13.0
FALL	3.0	9.0	12.0	13.0	17.3
ANNUAL	3.0	9.0	12.0	14.0	17.0

TABLE 11. Percent Occurrence Of The Differences In Windspeed (Knots), Berlin And Lindenberg, At 700 Millibar, 1200 Hours GMT (1974-78, 1981)

	0 TO 2	3 TO 5	6 TO 8	9 TO 11	12 TO 14	GT 15
JANUARY	34.74	30.53	20.00	10.53	3.16	1.05
FEBRUARY	45.54	24.75	21.78	5.94	.99	.99
MARCH	38.89	38.89	12.96	3.70	2.78	2.78
APRIL	49.57	33.91	9.57	4.35	.87	1.74
MAY	46.43	31.25	12.50	8.04	1.79	0.00
JUNE	52.33	26.74	17.44	3.49	0.00	0.00
JULY	52.75	29.57	12.09	2.20	2.20	2.20
AUGUST	60.00	26.67	9.52	2.86	.95	0.00
SEPTEMBER	44.44	38.52	8.15	6.67	1.48	.74
OCTOBER	38.52	34.81	17.04	8.15	.74	.74
NOVEMBER	41.03	33.33	18.80	3.42	2.56	.85
DECEMBER	44.94	33.71	12.36	4.49	3.37	1.12
FALL	41.34	35.66	14.47	[illegible]	1.55	[illegible]
WINTER	41.75	[illegible]	[illegible]	7.02	2.46	[illegible]
SPRING	45.97	[illegible]	11.64	5.37	1.79	[illegible]
SUMMER	55.32	[illegible]	12.77	[illegible]	[illegible]	.71
ANNUAL	[illegible]	[illegible]	[illegible]	[illegible]	1.72	[illegible]

TABLE 12. Cumulative Percent Occurrence Of The Differences In Windspeed (Knots), Berlin And Lindenberg, At 700 Millibar, 1200 Hours GMT (1974-78, 1981)

	0 TO 2	3 TO 5	6 TO 8	9 TO 11	12 TO 14	GT 15
JANUARY	34.74	65.26	85.26	95.79	98.95	100.00
FEBRUARY	45.54	70.30	92.08	98.02	99.01	100.00
MARCH	38.89	77.78	90.74	94.44	97.22	100.00
APRIL	49.57	83.48	93.04	97.39	98.26	100.00
MAY	46.43	77.68	90.18	98.21	100.00	100.00
JUNE	52.33	79.07	95.51	100.00	100.00	100.00
JULY	52.75	81.32	93.41	95.60	97.80	100.00
AUGUST	60.00	85.67	96.19	99.05	100.00	100.00
SEPTEMBER	44.44	82.96	91.11	97.78	99.26	100.00
OCTOBER	38.52	73.33	90.37	98.52	99.26	100.00
NOVEMBER	41.03	74.36	93.16	96.53	99.15	100.00
DECEMBER	44.94	78.65	91.01	95.51	98.88	100.00
FALL	41.34	77.00	91.47	97.67	99.22	100.00
WINTER	41.75	71.23	89.47	96.49	98.95	100.00
SPRING	45.07	77.70	91.34	95.72	98.51	100.00
SUMMER	55.32	82.52	95.39	96.23	99.29	100.00
ANNUAL	45.46	77.55	91.85	97.25	98.99	100.00

TABLE 13. 50, 90, 95, 97.5, And 99 Percentile Values Of The Differences In Windspeed (Knots), Berlin And Lindenberg, At 700 Millibar, 1200 Hours GMT (1974-78, 1981)

	50TH PERC	90TH PERC	95TH PERC	97.5 PERC	99TH PERC
JANUARY	4.0	9.5	11.0	12.8	14.0
FEBRUARY	3.0	8.0	9.0	10.5	14.0
MARCH	3.0	8.0	12.0	13.6	17.0
APRIL	2.5	7.0	10.0	11.1	17.3
MAY	3.0	8.2	10.0	11.0	12.2
JUNE	2.0	7.0	8.0	10.2	11.0
JULY	2.0	8.0	9.0	13.1	16.0
AUGUST	2.0	6.0	8.0	9.4	10.0
SEPTEMBER	3.0	7.0	10.0	11.0	16.1
OCTOBER	3.0	8.5	9.3	10.4	15.8
NOVEMBER	3.0	7.3	9.0	12.0	14.2
DECEMBER	3.0	7.0	11.9	13.2	14.2
WINTER	3.0	9.0	11.0	13.0	14.3
SPRING	3.0	8.0	10.0	12.0	17.0
SUMMER	2.0	7.0	8.0	10.0	12.4
FALL	3.0	8.0	10.0	11.0	13.1
ANNUAL	3.0	8.0	10.0	12.0	14.1

TABLE 14. Percent Occurrence Of The Differences In Windspeed (Knots), Berlin And Lindenberg, At 500 Millibar, 1200 Hours GMT (1974-78, 1981)

	0 TO 2	3 TO 5	6 TO 8	9 TO 11	12 TO 14	GT 15
JANUARY	31.58	26.32	25.26	7.37	0.00	9.47
FEBRUARY	31.68	44.55	12.87	4.95	1.98	3.96
MARCH	31.48	36.11	13.89	9.26	3.70	5.56
APRIL	33.91	33.91	22.61	2.61	5.22	1.74
MAY	41.07	38.39	10.71	6.25	2.68	.89
JUNE	58.14	20.93	6.98	8.14	3.49	2.33
JULY	43.96	32.97	16.48	1.10	2.20	3.30
AUGUST	40.00	39.05	14.29	3.81	.95	1.90
SEPTEMBER	31.11	32.59	17.78	11.11	4.44	2.96
OCTOBER	47.41	25.19	14.07	6.67	3.70	2.96
NOVEMBER	35.90	30.77	17.09	8.55	2.56	5.13
DECEMBER	35.96	34.83	19.10	5.62	1.12	3.37
FALL	38.24	29.46	16.29	8.79	3.62	3.62
WINTER	32.98	35.44	18.95	5.95	1.05	5.61
SPRING	35.52	36.12	15.92	5.97	3.48	2.99
SUMMER	46.81	31.56	12.77	4.25	2.13	2.48
ANNUAL	38.25	32.97	15.98	6.44	2.79	3.57

TABLE 15. Cumulative Percent Occurrence Of The Differences In Windspeed (Knots), Berlin And Lindenberg, At 500 Millibar, 1200 Hours GMT (1974-78, 1981)

	0 TO 2	3 TO 5	6 TO 8	9 TO 11	12 TO 14	GT 15
JANUARY	31.58	57.39	83.16	90.53	90.53	100.00
FEBRUARY	31.68	76.24	89.11	94.06	96.04	100.00
MARCH	31.48	67.59	81.48	90.74	94.44	100.00
APRIL	33.91	67.83	90.43	93.04	98.26	100.00
MAY	41.07	79.46	90.18	96.43	99.11	100.00
JUNE	58.14	79.07	86.05	94.19	97.67	100.00
JULY	43.96	76.92	93.41	94.51	96.70	100.00
AUGUST	40.00	79.05	93.33	97.14	98.10	100.00
SEPTEMBER	31.11	63.70	81.48	92.59	97.04	100.00
OCTOBER	47.41	72.59	86.67	93.33	97.04	100.00
NOVEMBER	35.90	66.67	83.76	92.31	94.87	100.00
DECEMBER	35.96	70.79	89.89	95.51	96.63	100.00
FALL	38.24	67.70	83.99	92.76	96.36	100.00
WINTER	32.98	68.42	87.37	93.33	94.39	100.00
SPRING	35.52	71.64	87.46	93.43	97.31	100.00
SUMMER	46.61	78.37	91.13	95.39	97.52	100.00
ANNUAL	38.25	71.22	87.20	93.64	96.43	100.00

TABLE 16. 50, 90, 95, 97.5, And 99 Percentile Values Of The Differences In Windspeed (Knots), Berlin And Lindenberg, At 500 Millibar, 1200 Hours GMT (1974-78, 1981)

	50TH PERC	90TH PERC	95TH PERC	97.5 PERC	99TH PERC
JANUARY	4.5	10.5	16.3	18.0	18.0
FEBRUARY	3.0	8.1	12.0	22.8	32.0
MARCH	4.0	11.0	15.0	16.6	21.0
APRIL	4.0	8.0	13.0	14.0	15.0
MAY	3.0	8.0	9.0	12.0	13.2
JUNE	2.0	9.4	13.0	14.3	21.3
JULY	3.0	8.0	10.4	16.3	17.0
AUGUST	3.0	7.0	9.0	10.3	15.0
SEPTEMBER	4.0	9.5	12.3	16.8	40.4
OCTOBER	3.0	10.0	13.0	15.4	19.1
NOVEMBER	3.5	10.0	14.2	16.0	30.2
DECEMBER	4.0	8.0	11.8	28.2	36.9
WINTER	4.0	10.0	16.0	19.0	36.0
SPRING	4.0	9.0	12.0	15.0	16.7
SUMMER	3.0	8.0	10.1	14.0	17.0
FALL	3.0	10.0	14.0	15.0	23.9
ANNUAL	3.0	9.0	13.0	15.0	22.1

TABLE 17. Total Observed Variability (Knots) And Linear Correlation Coefficient Of The Windspeed At The Specified Pressure Levels For Berlin And Lindenberg, 1200 Hours GMT (1974-78, 1981)

Pressure level (approx height in parenthesis)	Variability (knots)	Correlation
Surface	5.56	.712
1000 mb (Near surface)	6.08	.683
850 mb (1.5 km)	7.87	.889
700 mb (3.0 km)	7.13	.925
500 mb (5.5 km)	9.35	.924

TABLE 18. Percent Occurrence Of The Differences In Wind Direction (Degrees), Berlin And Lindenberg, At The Surface, 1200 Hours GMT (1974-78, 1981)

	0-29	30-59	60-89	90-119	120-149	150-180
JANUARY	75.79	15.84	4.21	1.05	1.05	1.05
FEBRUARY	69.31	21.78	5.94	0.00	2.97	0.00
MARCH	62.96	28.70	7.41	0.00	.93	0.00
APRIL	64.35	25.22	6.09	1.74	1.74	.87
MAY	56.25	28.57	8.04	3.57	2.68	.89
JUNE	61.63	24.42	2.33	4.65	2.33	4.65
JULY	67.03	27.47	1.10	2.20	2.20	0.00
AUGUST	65.71	25.71	7.62	0.00	0.00	.95
SEPTEMBER	68.15	18.52	5.93	3.70	1.48	2.22
OCTOBER	68.89	22.22	7.41	0.00	0.00	1.48
NOVEMBER	76.07	17.09	4.27	1.71	0.00	.85
DECEMBER	84.27	13.48	0.00	1.12	0.00	1.12
FALL	70.90	19.38	5.94	1.81	.52	1.55
WINTER	76.14	17.54	3.51	.70	1.40	.70
SPRING	61.19	27.46	7.16	1.79	1.79	.60
SUMMER	64.89	25.89	3.90	2.13	1.42	1.77
ANNUAL	68.19	22.50	5.26	1.58	1.24	1.15

TABLE 19. Cumulative Percent Occurrence Of The Differences In Wind Direction (Degrees), Berlin And Lindenberg, At The Surface, 1200 Hours GMT (1974-78, 1981)

	0-29	30-59	60-89	90-119	120-149	150-180
JANUARY	75.79	92.63	96.84	97.39	98.95	100.00
FEBRUARY	69.31	91.09	97.03	97.03	100.00	100.00
MARCH	62.96	91.67	99.07	99.07	100.00	100.00
APRIL	64.35	89.57	95.65	97.39	99.13	100.00
MAY	56.25	84.32	92.86	96.43	99.11	100.00
JUNE	61.63	85.05	89.37	93.02	95.35	100.00
JULY	67.03	94.51	95.60	97.80	100.00	100.00
AUGUST	65.71	91.43	99.05	99.05	99.05	100.00
SEPTEMBER	68.15	86.67	92.59	95.30	97.78	100.00
OCTOBER	68.69	91.11	95.52	96.52	98.52	100.00
NOVEMBER	76.07	93.16	97.44	99.15	99.15	100.00
DECEMBER	84.27	97.75	97.75	98.88	98.88	100.00
FALL	70.30	90.19	96.12	97.93	98.45	100.00
WINTER	76.14	93.53	97.19	97.39	99.30	100.00
SPRING	61.19	88.55	95.82	97.61	99.40	100.00
SUMMER	64.39	90.73	94.68	95.61	98.23	100.00
ANNUAL	68.19	90.63	95.97	97.60	99.34	100.00

TABLE 20. 50, 90, 95, 97.5, And 99 Percentile Values Of The Differences In Wind Direction (Degrees), Berlin And Lindenberg, At The Surface, 1200 Hours GMT (1974-78, 1981)

	50TH PERC	90TH PERC	95TH PERC	97.5 PERC	99TH PERC
JANUARY	17.5	47.5	71.3	116.9	145.0
FEBRUARY	20.0	55.0	70.0	101.4	135.0
MARCH	20.0	50.0	70.0	75.0	80.0
APRIL	20.0	57.5	85.0	112.5	135.3
MAY	20.0	70.0	97.0	121.0	141.8
JUNE	20.0	90.0	143.0	150.0	160.0
JULY	20.0	45.5	57.2	112.8	120.0
AUGUST	20.0	55.0	70.0	75.6	85.0
SEPTEMBER	20.0	70.0	100.0	148.9	166.8
OCTOBER	20.0	52.5	70.0	85.0	163.5
NOVEMBER	15.0	40.0	60.0	85.0	121.1
DECEMBER	15.0	30.0	42.3	94.0	120.5
WINTER	15.0	45.0	56.3	101.9	140.3
SPRING	20.0	50.0	80.0	113.3	140.0
SUMMER	20.0	55.0	90.0	120.0	160.0
FALL	20.0	55.0	81.9	103.3	160.7
ANNUAL	20.0	55.0	80.0	111.1	155.0

TABLE 21. Percent Occurrence Of The Differences In Wind Direction (Degrees), Berlin And Lindenberg, At 1000 Millibar, 1200 Hours GMT (1974-78, 1981)

	0-29	30-59	60-89	90-119	120-149	150-180
JANUARY	7[illegible].[illegible]4	15.79	3.25	0.00	2.11	0.00
FEBRUARY	73.27	18.31	4.35	.99	0.00	1.99
MARCH	71.26	21.30	6.47	0.00	.93	0.00
APRIL	69.57	20.67	6.96	.87	1.74	0.00
MAY	60.71	28.57	7.14	.39	2.55	0.00
JUNE	67.44	16.28	5.23	5.44	4.65	1.16
JULY	71.43	21.98	2.20	2.20	2.20	0.00
AUGUST	70.46	22.86	3.91	1.93	0.00	.93
SEPTEMBER	73.33	16.30	4.44	2.22	.74	2.22
OCTOBER	72.59	19.26	7.41	0.00	0.00	.74
NOVEMBER	80.34	15.33	2.56	.85	0.00	.85
DECEMBER	85.39	11.24	2.25	0.00	0.00	1.12
FALL	75.19	17.05	4.91	1.00	.25	1.55
WINTER	78.25	15.44	4.21	.35	.70	1.05
SPRING	67.1[illegible]	23.58	5.77	.60	1.77	0.00
SUMMER	69.86	20.57	4.26	2.48	2.13	.71
ANNUAL	72.61	19.1[illegible]	5.12	[illegible]	1.15	.85

TABLE 22. Cumulative Percent Occurrence Of The Differences In Wind Direction (Degrees), Berlin And Lindenberg, At 1000 Millibar, 1200 Hours GMT (1974-78, 1981)

	0-29	30-59	60-89	90-119	120-149	150-180
JANUARY	76.54	92.53	97.39	97.39	100.00	100.00
FEBRUARY	73.27	92.08	97.03	98.02	98.02	100.00
MARCH	71.30	92.59	99.07	99.07	100.00	100.00
APRIL	69.57	90.43	97.39	98.26	100.00	100.00
MAY	60.71	89.29	96.43	97.32	100.00	100.00
JUNE	67.44	83.72	93.72	94.19	98.84	100.00
JULY	71.43	92.41	95.53	97.80	100.00	100.00
AUGUST	70.48	93.33	97.14	99.05	99.05	100.00
SEPTEMBER	73.33	89.63	94.07	95.30	97.04	100.00
OCTOBER	72.59	91.85	98.26	99.26	99.26	100.00
NOVEMBER	80.34	95.73	98.29	99.15	99.15	100.00
DECEMBER	85.39	95.53	[illegible]	[illegible]	99.35	100.00
FALL	75.19	92.25	97.16	95.14	98.45	100.00
WINTER	78.25	93.53	97.39	98.25	99.35	100.00
SPRING	67.16	89.75	97.61	[illegible]	100.00	100.00
SUMMER	[illegible]	[illegible]	[illegible]	[illegible]	98.24	100.00
ANNUAL	73.51	91.73	[illegible]	[illegible]	[illegible]	100.00

TABLE 23. 50, 90, 95, 97.5, And 99 Percentile Values Of The Differences In Wind Direction (Degrees), Berlin And Lindenberg, At 1000 Millibar, 1200 Hours GMT (1974-78, 1981)

	50TH PERC	90TH PERC	95TH PERC	97.5 PERC	99TH PERC
JANUARY	15.0	45.0	71.3	103.3	135.0
FEBRUARY	15.0	55.0	65.0	84.7	150.0
MARCH	20.0	50.0	70.0	70.0	80.0
APRIL	20.0	55.0	62.5	85.6	121.5
MAY	20.0	60.0	80.0	100.0	131.8
JUNE	20.0	73.0	123.0	145.0	145.7
JULY	20.0	45.0	62.2	109.1	120.0
AUGUST	15.0	50.0	60.0	77.5	90.0
SEPTEMBER	15.0	60.0	95.0	151.9	161.8
OCTOBER	15.0	50.0	66.3	73.3	111.5
NOVEMBER	10.0	40.0	50.7	65.0	109.4
DECEMBER	15.0	35.0	44.5	60.0	72.1
WINTER	15.0	45.0	60.0	80.6	145.8
SPRING	20.0	55.0	70.0	86.9	130.0
SUMMER	20.0	55.0	90.0	120.0	145.0
FALL	15.0	45.5	70.0	95.0	155.0
ANNUAL	15.0	50.0	70.0	95.0	145.0

TABLE 24. Percent Occurrence Of The Differences In Wind Direction (Degrees), Berlin And Lindenberg, At 850 Millibar, 1200 Hours GMT (1974-78, 1981)

	0-29	30-59	60-89	90-119	120-149	150-179
JANUARY	83.15	13.68	1.05	2.11	0.00	0.00
FEBRUARY	96.14	3.91	3.36	0.00	0.00	.39
MARCH	84.26	9.39	7.41	0.00	0.00	0.00
APRIL	85.22	8.70	2.61	[illegible]	.37	0.00
MAY	83.93	3.93	1.79	3.57	0.00	1.79
JUNE	79.07	11.79	4.65	2.33	0.00	1.16
JULY	90.11	5.59	2.20	0.00	1.10	0.00
AUGUST	80.00	19.05	0.00	.95	0.00	0.00
SEPTEMBER	82.22	11.11	4.44	2.22	0.00	0.00
OCTOBER	73.52	15.30	2.36	.74	1.46	0.00
NOVEMBER	84.62	10.25	3.42	0.00	.85	.85
DECEMBER	92.13	5.62	0.00	0.00	1.12	1.12
FALL	81.68	[illegible]	2.62	1.13	.74	[illegible]
WINTER	87.02	[illegible]	1.75	.70	.35	.70
SPRING	[illegible]	[illegible]	[illegible]	[illegible]	.36	[illegible]
SUMMER	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
ANNUAL	[illegible]	[illegible]	[illegible]	[illegible]	.47	.47

TABLE 25. Cumulative Percent Occurrence Of The Differences In Wind Direction (Degrees), Berlin And Lindenberg, At 850 Millibar, 1200 Hours GMT (1974-78, 1981)

	0-29	30-59	60-89	90-119	120-149	150-180
JANUARY	83.15	95.74	97.79	100.00	100.00	100.00
FEBRUARY	86.14	97.05	99.01	99.51	99.51	100.00
MARCH	84.25	92.59	100.00	100.00	100.00	100.00
APRIL	85.22	93.91	96.52	99.13	100.00	100.00
MAY	83.93	92.35	94.64	98.21	99.21	100.00
JUNE	79.07	91.45	96.61	98.84	99.34	100.00
JULY	80.11	95.70	98.90	99.90	100.00	100.00
AUGUST	86.00	98.05	99.05	100.00	100.00	100.00
SEPTEMBER	82.22	93.33	97.78	100.00	100.00	100.00
OCTOBER	78.82	94.51	97.73	99.82	100.00	100.00
NOVEMBER	84.62	94.37	98.29	99.24	99.15	100.00
DECEMBER	82.13	97.75	97.75	97.75	98.[illegible]	100.00
FALL	81.[illegible]	94.[illegible]	97.[illegible]	[illegible]	99.74	100.00
WINTER	87.[illegible]	95.[illegible]	[illegible]	[illegible]	99.[illegible]	100.00
SPRING	84.[illegible]	93.13	97.[illegible]	[illegible]	[illegible]	[illegible]
SUMMER	[illegible]	95.[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
ANNUAL	[illegible]	94.[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

TABLE 26. 50, 90, 95, 97.5, And 99 Percentile Values Of The Differences In Wind Direction (Degrees), Berlin And Lindenberg, At 850 Millibar, 1200 Hours GMT (1974-78, 1981)

	50TH PERC	90TH PERC	95TH PERC	97.5 PERC	99TH PERC
JANUARY	10.0	37.5	51.3	73.1	95.0
FEBRUARY	10.0	31.5	55.0	65.0	75.0
MARCH	10.0	38.0	65.0	71.5	75.0
APRIL	10.0	42.5	62.5	95.0	112.3
MAY	15.0	41.0	86.0	106.0	171.2
JUNE	10.0	55.0	71.5	110.0	116.3
JULY	10.0	25.5	55.0	75.0	75.0
AUGUST	15.0	35.0	41.3	51.9	55.0
SEPTEMBER	10.0	45.0	60.0	79.4	102.0
OCTOBER	10.0	42.5	56.3	77.5	121.8
NOVEMBER	10.0	40.0	47.2	55.0	145.9
DECEMBER	5.0	25.0	37.3	69.5	123.3
WINTER	10.0	30.0	51.3	55.0	103.0
SPRING	10.0	42.5	66.3	95.0	115.3
SUMMER	10.0	40.0	55.0	75.0	110.0
FALL	10.0	40.0	50.0	70.0	115.7
ANNUAL	10.0	40.0	60.0	75.0	110.5

TABLE 27. Percent Occurrence Of The Differences In Wind Direction (Knots), Berlin And Lindenberg, At 700 Millibar, 1200 Hours GMT (1974-78, 1981)

	0-29	30-59	60-89	90-119	120-149	150-1[illegible]
JANUARY	92.63	5.26	1.05	0.00	0.00	1.05
FEBRUARY	88.12	9.90	.99	.99	0.00	0.00
MARCH	94.44	2.78	1.85	0.00	0.00	.93
APRIL	86.96	6.96	3.48	1.74	0.00	.87
MAY	88.39	7.14	3.57	.89	0.00	0.00
JUNE	83.72	12.79	2.33	0.00	0.00	1.16
JULY	92.31	4.40	3.30	0.00	0.00	0.00
AUGUST	85.71	5.67	4.76	2.36	0.00	0.00
SEPTEMBER	89.59	3.15	.74	1.43	0.00	.74
OCTOBER	94.07	2.22	.74	2.22	.74	0.00
NOVEMBER	94.02	2.56	1.71	1.71	0.00	0.00
DECEMBER	88.76	7.87	2.25	0.00	0.00	1.12
FALL	92.25	4.39	1.03	1.81	.26	.26
WINTER	89.82	7.72	1.40	.35	0.00	.70
SPRING	89.85	5.67	2.99	.30	0.00	.30
SUMMER	87.23	7.30	3.55	1.05	0.00	.26
ANNUAL	89.96	5.21	2.17	1.09	[illegible]	[illegible]

TABLE 28. Cumulative Percent Occurrence Of The Differences In Wind Direction (Degrees), Berlin And Lindenberg, At 700 Millibar, 1200 Hours GMT (1974-78, 1981)

	0-29	30-59	60-89	90-119	120-149	150-180
JANUARY	92.63	97.89	98.95	98.95	98.95	100.00
FEBRUARY	88.12	98.02	99.01	100.00	100.00	100.00
MARCH	94.44	97.22	99.07	99.07	99.07	100.00
APRIL	85.96	93.91	97.39	99.13	99.13	100.00
MAY	83.39	95.54	99.11	100.00	100.00	100.00
JUNE	82.72	96.51	98.84	98.84	98.84	100.00
JULY	92.31	96.70	100.00	100.00	100.00	100.00
AUGUST	85.71	92.38	97.14	100.00	100.00	100.00
SEPTEMBER	86.59	97.04	97.78	99.26	99.26	100.00
OCTOBER	94.07	96.30	97.04	99.26	100.00	100.00
NOVEMBER	94.02	95.58	98.20	100.00	100.00	100.00
DECEMBER	88.76	96.63	98.88	98.88	98.88	100.00
FALL	92.25	96.64	97.57	99.44	99.74	100.00
WINTER	89.82	97.54	98.95	99.30	99.30	100.00
SPRING	89.85	95.52	98.51	99.40	99.40	100.00
SUMMER	87.23	95.04	98.58	99.65	99.65	100.00
ANNUAL	89.99	96.20	98.37	99.45	99.53	100.00

TABLE 29. 50, 90, 95, 97.5 And 99 Percentile Values Of The Differences In Wind Direction (Degrees), Berlin And Lindenberg, At 700 Millibar, 1200 Hours GMT (1974-78, 1981)

	50TH PERC	90TH PERC	95TH PERC	97.5 PERC	99TH PERC
JANUARY	5.0	20.0	35.0	50.6	60.0
FEBRUARY	10.0	30.5	40.0	45.0	60.0
MARCH	5.0	25.0	50.0	56.5	70.0
APRIL	10.0	30.0	76.3	86.3	111.8
MAY	10.0	31.0	55.0	72.0	86.2
JUNE	10.0	45.0	55.0	72.3	96.9
JULY	10.0	25.0	42.2	51.4	65.0
AUGUST	10.0	42.5	73.8	85.9	100.0
SEPTEMBER	5.0	30.0	47.5	71.3	121.3
OCTOBER	5.0	25.0	30.0	98.8	119.0
NOVEMBER	5.0	16.5	30.0	75.0	90.9
DECEMBER	5.0	25.0	37.3	71.1	84.3
WINTER	5.0	30.0	36.3	46.9	78.0
SPRING	10.0	27.5	55.0	81.9	96.5
SUMMER	10.0	40.0	55.5	70.0	91.8
FALL	5.0	25.0	41.9	73.3	96.3
ANNUAL	10.0	25.0	50.0	73.0	95.0

TABLE 30. Percent Occurrence Of The Differences In Wind Direction (Degrees), Berlin And Lindenberg, At 500 Millibar, 1200 Hours GMT (1974-78, 1981)

	0-29	30-59	60-89	90-119	120-149	150-180
JANUARY	97.89	2.11	0.00	0.00	0.00	0.00
FEBRUARY	86.14	6.93	4.95	1.98	0.00	0.00
MARCH	94.44	5.56	0.00	0.00	0.00	0.00
APRIL	90.43	5.22	2.61	.87	.87	0.00
MAY	92.56	4.46	2.98	0.00	0.00	0.00
JUNE	89.53	5.81	1.16	1.16	0.00	2.33
JULY	93.41	5.49	1.10	0.00	0.00	0.00
AUGUST	96.19	3.81	0.00	0.00	0.00	0.00
SEPTEMBER	93.33	5.19	.74	0.00	.74	0.00
OCTOBER	94.07	2.96	0.00	1.48	.74	.74
NOVEMBER	95.73	3.42	0.00	.85	0.00	0.00
DECEMBER	91.01	6.74	1.12	1.12	0.00	0.00
FALL	94.32	3.83	.26	.78	.52	.26
WINTER	91.58	5.26	2.11	1.05	0.00	0.00
SPRING	92.54	5.07	1.79	.30	.30	0.00
SUMMER	93.26	4.96	.71	.36	0.00	.71
ANNUAL	93.02	4.73	1.16	.62	.23	.23

TABLE 31. Cumulative Percent Occurrence Of The Differences in Wind Direction (Degrees), Berlin And Lindenberg, At 500 Millibar, 1200 Hours GMT (1974-78, 1981)

	0-29	30-59	60-89	90-119	120-149	150-179
JANUARY	97.39	100.00	100.00	100.00	100.00	100.00
FEBRUARY	86.14	93.07	99.02	100.00	100.00	100.00
MARCH	94.44	100.00	100.00	100.00	100.00	100.00
APRIL	90.43	95.65	98.26	99.13	100.00	100.00
MAY	92.86	97.32	100.00	100.00	100.00	100.00
JUNE	89.53	95.35	96.51	97.67	97.67	100.00
JULY	93.41	95.90	100.00	100.00	100.00	100.00
AUGUST	96.19	100.00	100.00	100.00	100.00	100.00
SEPTEMBER	93.33	98.52	99.26	99.26	100.00	100.00
OCTOBER	94.07	97.04	97.04	98.52	99.26	100.00
NOVEMBER	95.73	99.15	99.15	100.00	100.00	100.00
DECEMBER	91.01	97.75	98.88	100.00	100.00	100.00
FALL	94.32	98.13	98.45	99.22	99.74	100.00
WINTER	91.58	95.34	98.75	100.00	100.00	100.00
SPRING	92.54	97.51	99.00	99.70	100.00	100.00
SUMMER	93.26	98.23	99.34	99.22	99.24	100.00
ANNUAL	93.02	97.75	98.91	99.53	99.77	100.00

TABLE 32. 50, 90, 95, 97.5, And 99 Percentile Values Of The Differences In Wind Direction (Degrees), Berlin And Lindenberg, At 500 Millibar, 1200 Hours GMT (1974-78, 1981)

	50TH PERC	90TH PERC	95TH PERC	97.5 PERC	99TH PERC
JANUARY	5.0	15.0	20.0	20.0	20.0
FEBRUARY	7.5	40.5	60.0	72.4	85.0
MARCH	5.0	15.0	30.0	35.0	35.0
APRIL	10.0	20.0	45.0	57.5	111.5
MAY	5.0	25.0	34.0	44.0	66.2
JUNE	10.0	29.0	56.0	117.5	160.0
JULY	5.0	25.0	32.2	50.0	50.0
AUGUST	10.0	20.0	25.0	31.9	35.0
SEPTEMBER	5.0	25.0	35.0	41.9	81.0
OCTOBER	5.0	20.0	28.8	58.1	127.8
NOVEMBER	5.0	20.0	25.0	30.0	59.4
DECEMBER	5.0	20.0	35.0	41.7	67.7
WINTER	5.0	25.0	36.3	50.5	85.7
SPRING	5.0	25.0	35.0	50.5	78.5
SUMMER	5.0	25.0	35.0	50.0	77.2
FALL	5.0	20.0	31.9	45.0	106.0
ANNUAL	5.0	25.0	35.0	50.0	90.0

TABLE 33. Percent Occurrence Of The Wind-Shear (Knots) Between Berlin And Lindenberg At The Surface, 1200 Hours GMT 1974-78, 1981)

	0 TO 2	3 TO 5	6 TO 8	9 TO 11	12 TO 14	GT 15
JANUARY	41.05	40.00	13.68	2.11	0.00	3.16
FEBRUARY	38.61	53.47	4.95	2.97	0.00	0.00
MARCH	25.93	53.70	13.89	4.63	.93	.93
APRIL	31.30	44.35	18.26	4.35	1.74	0.00
MAY	34.92	41.96	17.36	2.58	.89	1.79
JUNE	25.58	39.53	23.26	8.14	3.49	0.00
JULY	34.07	42.86	15.38	5.49	1.10	1.10
AUGUST	39.05	40.00	17.14	.95	.95	1.90
SEPTEMBER	34.07	47.41	13.33	2.22	.74	2.22
OCTOBER	45.19	40.74	8.89	4.44	.74	0.00
NOVEMBER	38.46	45.30	11.11	.85	2.56	1.71
DECEMBER	37.08	44.94	12.36	2.25	2.25	1.12
FALL	39.28	44.44	11.11	2.59	1.29	1.29
WINTER	38.95	45.32	10.18	3.46	.70	1.40
SPRING	30.75	45.57	16.72	3.88	1.19	.90
SUMMER	33.33	40.78	18.44	4.61	1.77	1.06
ANNUAL	35.69	44.51	13.95	3.39	1.24	1.16

TABLE 34. Cumulative Percent Occurrence Of The Wind-Shear (Knots) Between Berlin And Lindenberg At The Surface, 1200 Hours GMT (1974-78, 1981)

	0 TO 2	3 TO 5	6 TO 8	9 TO 11	12 TO 14	GT 15
JANUARY	41.05	81.05	94.73	96.84	96.84	100.00
FEBRUARY	38.61	92.03	97.03	100.00	100.00	100.00
MARCH	25.93	73.53	93.72	95.15	99.07	100.00
APRIL	31.30	75.55	93.91	98.25	100.00	100.00
MAY	34.82	75.79	94.64	97.32	99.21	100.00
JUNE	25.58	65.12	89.37	96.51	100.00	100.00
JULY	34.07	76.92	92.31	97.80	98.90	100.00
AUGUST	39.05	79.05	96.19	97.14	98.10	100.00
SEPTEMBER	34.07	81.48	94.31	97.04	97.78	100.00
OCTOBER	45.19	85.93	94.81	99.26	100.00	100.00
NOVEMBER	38.40	83.70	94.97	95.73	99.29	100.00
DECEMBER	37.08	82.02	94.33	96.63	99.55	100.00
FALL	39.23	83.72	94.49	97.42	99.71	100.00
WINTER	38.95	85.26	95.44	97.59	99.30	100.00
SPRING	30.75	77.31	94.73	97.91	99.10	100.00
SUMMER	33.33	74.11	92.55	97.15	98.94	100.00
ANNUAL	35.69	80.23	94.25	97.53	99.34	100.00

TABLE 35. 50, 90, 95, 97.5, And 99 Percentile Values Of The Wind-Shear (Knots) Between Berlin And Lindenberg At The Surface, 1200 Hours GMT (1974-78, 1981)

	50TH PERC	90TH PERC	95TH PERC	97.5 PERC	99TH PERC
JANUARY	3.5	7.5	8.4	17.4	21.2
FEBRUARY	3.5	5.7	7.1	8.6	9.9
MARCH	4.0	7.5	9.5	10.0	14.7
APRIL	4.0	7.3	9.2	9.9	12.4
MAY	4.0	7.5	9.1	11.1	22.2
JUNE	4.6	8.9	10.1	12.2	12.8
JULY	4.1	8.0	9.9	12.0	13.9
AUGUST	3.4	7.1	8.5	10.6	23.0
SEPTEMBER	3.5	7.1	8.4	15.8	22.6
OCTOBER	3.1	6.4	8.8	11.2	12.6
NOVEMBER	3.6	6.9	8.3	13.3	36.0
DECEMBER	3.8	7.1	9.3	13.6	14.7
WINTER	3.5	7.0	8.0	10.0	15.7
SPRING	4.0	7.5	9.3	10.7	16.6
SUMMER	4.0	8.1	9.7	12.1	16.1
FALL	3.4	7.0	9.0	12.2	15.5
ANNUAL	3.7	7.3	9.4	11.7	18.3

TABLE 36. Percent Occurrence Of The Wind-Shear (Knots) Between Berlin And Lindenberg At 1000 Millibar, 1200 Hours GMT (1974-78, 1981)

	0 TO 2	3 TO 5	6 TO 8	9 TO 11	12 TO 14	GT 15
JANUARY	26.32	45.26	14.74	11.58	0.00	2.11
FEBRUARY	28.71	53.47	9.90	4.95	.99	1.98
MARCH	25.00	52.78	16.67	3.70	.93	.93
APRIL	26.96	45.22	21.74	5.22	.87	0.00
MAY	31.25	46.43	16.96	3.57	.89	.89
JUNE	22.09	45.35	22.09	6.98	3.49	0.00
JULY	29.67	48.35	15.38	5.49	1.10	0.00
AUGUST	30.48	51.43	14.29	2.86	.95	0.00
SEPTEMBER	31.11	43.70	17.78	2.22	1.48	3.70
OCTOBER	33.33	48.39	12.59	3.70	1.48	0.00
NOVEMBER	29.06	45.30	18.30	4.27	1.71	.85
DECEMBER	34.83	44.94	13.48	3.37	2.25	1.12
FALL	31.27	45.99	15.23	3.35	1.55	1.55
WINTER	29.82	43.07	12.63	6.67	1.05	1.75
SPRING	27.76	48.05	18.51	4.13	.90	[illegible]
SUMMER	27.66	48.58	17.02	4.90	1.77	[illegible]
ANNUAL	29.25	47.55	16.21	4.55	1.32	[illegible]

TABLE 37. Cumulative Percent Occurrence Of The Wind-Shear (Knots) Between Berlin And Lindenberg At 1000 Millibar, 1200 Hours GMT (1974-78, 1981)

	0 TO 2	3 TO 5	6 TO 8	9 TO 11	12 TO 14	GT 15
JANUARY	26.32	71.59	86.32	97.99	97.89	100.00
FEBRUARY	28.71	32.13	92.09	97.03	98.02	100.00
MARCH	25.00	77.73	94.44	98.15	99.07	100.00
APRIL	26.96	72.17	93.91	99.13	100.00	100.00
MAY	31.25	77.68	94.64	98.21	99.11	100.00
JUNE	22.09	67.44	89.53	96.51	100.00	100.00
JULY	29.67	78.02	93.41	98.90	100.00	100.00
AUGUST	30.48	31.90	96.13	99.35	100.00	100.00
SEPTEMBER	31.11	74.31	92.59	94.81	96.30	100.00
OCTOBER	33.33	32.22	94.81	98.52	100.00	100.00
NOVEMBER	29.06	74.36	93.16	97.44	99.15	100.00
DECEMBER	34.83	79.79	93.26	96.63	98.86	100.00
FALL	31.27	77.25	93.54	96.90	98.45	100.00
WINTER	29.92	77.39	90.53	97.19	98.25	100.00
SPRING	27.76	75.32	94.33	98.51	99.40	100.00
SUMMER	27.66	75.24	93.75	98.23	100.00	100.00
ANNUAL	29.25	75.30	93.02	97.57	98.99	100.00

TABLE 38. 50, 90, 95, 97.5, And 99 Percentile Values Of The Wind-Shear (Knots) Between Berlin And Lindenberg At 1000 Millibar, 1200 Hours GMT (1974-78, 1981)

	50TH PERC	90TH PERC	95TH PERC	97.5 PERC	99TH PERC
JANUARY	4.4	9.2	10.1	14.[illegible]	21.2
FEBRUARY	4.0	7.3	9.3	11.9	25.0
MARCH	4.2	7.8	9.1	9.4	14.7
APRIL	4.3	8.1	9.0	11.4	11.7
MAY	4.4	7.6	8.5	9.4	15.8
JUNE	4.8	8.3	10.4	12.0	12.5
JULY	4.3	7.6	9.4	11.4	11.9
AUGUST	3.5	7.0	8.4	9.4	10.8
SEPTEMBER	4.1	7.6	12.2	13.8	25.0
OCTOBER	3.7	7.0	8.8	10.3	13.1
NOVEMBER	4.2	7.8	9.7	11.4	14.2
DECEMBER	4.0	7.3	10.0	13.1	14.2
WINTER	4.0	8.5	10.0	12.8	21.8
SPRING	4.3	8.0	9.0	10.5	14.3
SUMMER	4.2	8.0	9.6	11.2	12.2
FALL	4.0	7.5	9.8	12.8	16.5
ANNUAL	4.1	7.9	9.6	11.5	14.9

TABLE 39. Percent Occurrence Of The Wind-Shear (Knots) Between Berlin And Lindenberg At 850 Millibar, 1200 Hours GMT (1974-78, 1981)

	0 TO 2	3 TO 5	6 TO 8	9 TO 11	12 TO 14	GT 15
JANUARY	7.37	35.34	17.89	14.74	11.58	11.58
FEBRUARY	13.86	47.52	25.74	4.95	5.94	1.98
MARCH	21.30	31.48	25.93	9.26	6.48	5.56
APRIL	25.22	33.04	25.22	7.83	2.61	6.09
MAY	14.29	49.11	18.75	10.71	4.46	2.68
JUNE	29.07	37.21	17.44	9.30	3.49	3.49
JULY	17.58	43.96	28.57	5.49	3.30	1.10
AUGUST	20.95	41.90	23.81	9.52	1.90	1.90
SEPTEMBER	19.26	35.56	22.96	11.85	3.70	6.67
OCTOBER	21.48	37.04	17.78	12.59	3.70	7.41
NOVEMBER	11.97	33.45	17.95	12.82	10.26	8.55
DECEMBER	16.85	23.09	22.47	15.73	7.87	8.99
FALL	17.83	35.95	19.64	12.40	5.68	7.49
WINTER	12.63	37.89	22.11	11.58	8.42	7.37
SPRING	20.30	37.91	23.23	9.25	4.48	4.73
SUMMER	22.34	41.13	23.40	3.16	2.84	2.13
ANNUAL	18.31	38.32	21.95	10.47	5.35	5.59

TABLE 40. Cumulative Percent Occurrence Of The Wind-Shear (Knots) Between Berlin And Lindenberg At 850 Millibar, 1200 Hours GMT (1974-78, 1981)

	0 TO 2	3 TO 5	6 TO 8	9 TO 11	12 TO 14	GT 15
JANUARY	7.37	44.21	62.11	75.34	89.42	100.00
FEBRUARY	13.26	61.39	87.13	92.06	98.02	100.00
MARCH	21.30	52.73	78.70	87.96	94.44	100.00
APRIL	25.22	53.26	83.43	91.30	93.91	100.00
MAY	14.29	63.39	82.14	92.86	97.32	100.00
JUNE	29.07	66.28	83.72	93.02	96.51	100.00
JULY	17.58	61.54	90.11	95.60	98.90	100.00
AUGUST	20.95	62.35	86.67	96.19	98.10	100.00
SEPTEMBER	19.26	54.31	77.78	89.63	93.33	100.00
OCTOBER	21.43	58.52	76.30	88.89	92.59	100.00
NOVEMBER	11.97	50.43	68.38	81.20	91.45	100.00
DECEMBER	16.85	44.94	67.42	83.15	91.01	100.00
FALL	17.35	54.73	74.42	86.32	92.51	100.00
WINTER	12.63	50.53	72.63	84.21	92.63	100.00
SPRING	20.30	53.21	81.40	90.75	95.22	100.00
SUMMER	22.34	63.43	86.38	95.04	97.97	100.00
ANNUAL	18.31	56.53	73.59	89.05	94.41	100.00

TABLE 41. 50, 90, 95, 97.5, And 99 Percentile Values Of The Wind-Shear (Knots) Between Berlin And Lindenberg At 850 Millibar, 1200 Hours GMT (1974-78, 1981)

	50TH PERC	90TH PERC	95TH PERC	97.5 PERC	99TH PERC
JANUARY	7.1	15.1	17.5	19.0	20.4
FEBRUARY	4.9	9.6	13.2	14.7	15.1
MARCH	5.5	12.8	16.4	23.7	36.0
APRIL	5.1	11.3	15.0	15.7	19.3
MAY	4.9	11.2	12.8	14.5	16.6
JUNE	4.2	10.2	14.6	15.1	15.3
JULY	5.0	8.8	11.0	13.9	14.3
AUGUST	4.7	10.3	11.3	13.1	16.7
SEPTEMBER	5.3	11.3	15.3	19.7	23.5
OCTOBER	5.2	13.0	17.4	21.0	25.9
NOVEMBER	5.9	13.7	16.4	18.5	27.5
DECEMBER	6.3	13.0	19.4	21.9	22.8
WINTER	5.9	13.7	16.6	20.5	22.8
SPRING	5.1	11.7	14.6	17.0	24.3
SUMMER	4.8	9.9	11.6	14.5	16.2
FALL	5.5	13.2	17.4	19.7	23.6
ANNUAL	5.2	12.3	15.1	13.1	22.0

TABLE 42. Percent Occurrence Of The Wind-Shear (Knots) Between Berlin And Lindenberg At 700 Millibar, 1200 Hours GMT (1974-78, 1981)

	0 TO 2	3 TO 5	6 TO 8	9 TO 11	12 TO 14	GT 15
JANUARY	12.63	40.00	25.25	10.53	7.37	4.21
FEBRUARY	18.81	30.69	30.69	15.84	1.98	1.98
MARCH	23.15	38.39	15.57	9.25	7.41	4.63
APRIL	27.83	33.04	23.48	9.57	4.35	1.74
MAY	29.46	31.25	21.43	12.50	2.68	2.68
JUNE	24.42	40.70	25.58	6.98	1.16	1.16
JULY	29.67	36.26	20.88	2.20	6.59	4.40
AUGUST	29.52	37.14	23.81	6.67	.95	1.90
SEPTEMBER	26.67	37.78	17.78	8.89	6.67	2.22
OCTOBER	18.52	45.93	17.78	8.89	3.70	5.19
NOVEMBER	22.22	29.06	29.91	9.40	7.69	1.71
DECEMBER	20.22	37.08	20.22	8.99	8.99	4.49
FALL	22.46	37.88	21.45	9.04	5.94	3.10
WINTER	17.19	35.79	25.61	11.93	5.96	3.51
SPRING	26.87	34.33	22.60	10.45	4.78	2.99
SUMMER	28.01	37.94	23.40	5.32	2.84	2.48
ANNUAL	23.66	36.54	22.58	9.23	4.97	3.03

TABLE 43. Cumulative Percent Occurrence Of The Wind-Shear (Knots) Between Berlin And Lindenberg At 700 Millibar, 1200 Hours BMT (1974-78, 1981)

	0 TO 2	3 TO 5	6 TO 8	9 TO 11	12 TO 14	GT 15
JANUARY	12.63	52.63	77.89	86.42	95.79	100.00
FEBRUARY	18.81	49.50	80.20	96.04	98.02	100.00
MARCH	23.15	52.04	78.70	87.96	95.37	100.00
APRIL	27.83	50.37	84.35	93.91	98.26	100.00
MAY	29.46	50.71	82.14	94.64	97.32	100.00
JUNE	24.42	65.12	90.70	97.67	98.84	100.00
JULY	29.67	65.93	86.91	89.01	95.60	100.00
AUGUST	29.52	66.67	90.43	97.14	98.10	100.00
SEPTEMBER	26.67	64.44	82.22	91.11	97.78	100.00
OCTOBER	18.52	54.44	82.22	91.11	94.81	100.00
NOVEMBER	22.22	51.28	81.20	90.60	98.29	100.00
DECEMBER	20.22	57.30	77.53	86.52	95.51	100.00
FALL	22.46	60.47	81.91	90.96	96.90	100.00
WINTER	17.19	52.93	75.60	90.55	96.49	100.00
SPRING	26.87	51.19	81.79	92.24	97.01	100.00
SUMMER	28.01	65.96	89.35	94.55	97.52	100.00
ANNUAL	23.66	60.20	82.73	92.01	96.47	100.00

TABLE 44. 50, 90, 95, 97.5, And 99 Percentile Values Of The Wind-Shear (Knots) Between Berlin And Lindenberg At 700 Millibar, 1200 Hours GMT (1974-78, 1981)

	50TH PERC	90TH PERC	95TH PERC	97.5 PERC	99TH PERC
JANUARY	5.4	12.1	14.3	[illegible]	22.3
FEBRUARY	6.0	10.0	11.5	14.0	17.8
MARCH	4.8	12.5	14.9	17.2	23.1
APRIL	4.7	10.2	12.2	14.2	19.8
MAY	4.4	10.7	12.1	14.3	18.0
JUNE	4.1	8.6	10.3	11.4	14.1
JULY	4.6	12.7	14.1	17.4	18.6
AUGUST	4.6	8.9	11.0	12.5	15.1
SEPTEMBER	4.5	11.3	13.3	16.3	25.6
OCTOBER	5.0	11.3	14.2	21.7	27.1
NOVEMBER	5.5	10.7	12.8	14.4	19.7
DECEMBER	5.4	12.8	14.7	15.3	16.6
WINTER	5.5	11.7	14.2	16.6	20.5
SPRING	4.7	10.9	13.9	15.9	23.5
SUMMER	4.4	9.1	12.7	14.5	16.4
FALL	5.0	11.2	13.9	17.6	22.5
ANNUAL	4.9	10.9	13.2	16.2	20.4

TABLE 45. Percent Occurrence Of The Wind-Shear (Knots) Between Berlin And Lindenberg At 500 Millibar, 1200 Hours GMT (1974-78, 1981)

	0 TO 2	3 TO 5	6 TO 8	9 TO 11	12 TO 14	GT 15
JANUARY	8.42	24.21	30.53	16.34	6.32	13.68
FEBRUARY	11.38	40.59	24.75	8.91	6.93	6.93
MARCH	14.81	37.96	23.15	12.04	3.70	8.33
APRIL	11.30	35.65	29.57	10.43	6.96	6.09
MAY	24.11	37.50	20.54	10.71	3.57	3.57
JUNE	25.58	33.72	23.26	6.98	4.65	5.81
JULY	23.08	33.46	17.58	9.89	2.20	8.79
AUGUST	15.24	49.52	24.76	4.76	2.86	2.86
SEPTEMBER	15.56	37.04	18.52	14.07	7.41	7.41
OCTOBER	20.74	37.04	20.74	9.63	3.70	8.15
NOVEMBER	15.38	27.35	27.35	17.09	5.13	7.69
DECEMBER	14.61	28.09	31.46	11.24	6.74	7.87
FALL	17.31	34.11	21.96	13.44	5.43	7.75
WINTER	11.58	31.23	28.77	12.28	6.67	9.47
SPRING	16.72	37.01	24.43	11.04	4.76	5.97
SUMMER	20.92	41.13	21.99	7.09	3.19	5.67
ANNUAL	16.68	35.76	24.13	11.17	5.04	7.21

TABLE 46. Cumulative Percent Occurrence Of The Wind-Shear (Knots) Between Berlin And Lindenberg At 500 Mililbar, 1200 Hours GMT (1974-78, 1981)

	0 TO 2	3 TO 5	6 TO 8	9 TO 11	12 TO 14	GT 15
JANUARY	8.42	32.53	63.16	80.00	96.32	100.00
FEBRUARY	11.38	52.43	77.23	86.14	9[illegible].07	100.00
MARCH	14.81	52.73	75.93	87.96	91.67	100.00
APRIL	11.30	45.96	76.52	86.96	93.91	100.00
MAY	24.11	51.61	92.14	92.35	96.43	100.00
JUNE	25.58	59.30	82.56	89.53	94.19	100.00
JULY	23.08	51.54	79.12	89.01	91.21	100.00
AUGUST	15.24	54.76	89.52	94.29	97.14	100.00
SEPTEMBER	15.56	52.59	71.11	85.19	92.59	100.00
OCTOBER	20.74	57.78	73.52	86.15	91.35	100.00
NOVEMBER	15.38	42.74	70.09	87.13	92.31	100.00
DECEMBER	14.61	42.70	74.16	85.39	92.13	100.00
FALL	17.31	51.42	73.39	86.32	92.25	100.00
WINTER	11.58	42.51	71.58	85.35	90.53	100.00
SPRING	16.72	53.73	78.21	89.25	94.03	100.00
SUMMER	20.92	52.06	84.04	91.13	94.33	100.00
ANNUAL	16.6[illegible]	52.44	76.57	87.74	92.79	100.00

TABLE 47. 50, 90, 95, 97.5, And 99 Percentile Values Of The Wind-Shear (Knots) Between Berlin And Lindenberg At 500 Millibar, 1200 Hours GMT (1974-78, 1981)

	50TH PERC	90TH PERC	95TH PERC	97.5 PERC	99TH PERC
JANUARY	7.7	16.1	18.3	20.3	21.4
FEBRUARY	5.6	13.0	19.5	28.7	32.5
MARCH	5.2	12.0	19.6	20.8	23.3
APRIL	6.0	13.3	15.1	18.3	32.4
MAY	5.0	11.0	13.7	16.5	23.7
JUNE	4.9	12.2	17.3	19.4	25.2
JULY	4.7	12.4	16.0	21.1	22.7
AUGUST	5.0	9.0	12.0	14.8	16.9
SEPTEMBER	5.9	13.4	17.0	39.0	44.0
OCTOBER	5.2	13.9	17.7	22.7	28.5
NOVEMBER	6.7	14.0	17.1	19.7	31.0
DECEMBER	6.5	14.0	19.6	30.6	43.6
WINTER	6.6	14.3	19.4	27.5	43.7
SPRING	5.5	12.1	15.6	20.9	26.9
SUMMER	4.9	11.7	15.8	17.8	20.9
FALL	5.9	13.9	17.7	22.1	34.6
ANNUAL	5.7	13.1	17.1	21.3	32.6

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